

Hybrid Empirical Method: Evaluation of Ground-Motion Prediction Equations for Central and Eastern North America

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Ground-motion prediction equations (GMPEs) and ground-motion adjustment factors developed using the Hybrid Empirical Method (HEM) are used in seismic hazard analyses throughout the world as an alternative to GMPEs developed from the more traditional empirical and simulation methods. The widespread application of the HEM has made it a viable approach for developing GMPEs in regions where there are few strong-motion recordings but where there are ample weak-motion data from small-magnitude earthquakes. The HEM uses empirical estimates of ground motion in one region (the host region) to provide estimates of ground motion in another region (the target region) by taking into account the differences in stress drop, source properties, crustal damping, regional crustal structure, and generic site conditions (amplification and damping) between the two regions. Empirical ground motion estimates in the host region are modified for use in the target region using target/host regional adjustment factors estimated from stochastic simulations that incorporate seismological models derived from weak-motion data. I published a formal mathematical framework for the HEM in 2003 and used seismological models for western North America (WNA) and eastern North America (ENA) to derive an ENA hybrid empirical hard-rock GMPE for PGA, PGV and 5% damped linear elastic response spectra. This GMPE was updated in 2007 and summarized in tabular rather than equation format. These applications identified several strengths and weaknesses in the HEM approach that one should be aware of before using GMPEs based on this method.

The most common application of the HEM has been in the development of GMPEs for ENA, two of which were used in the 2008 U.S. national seismic hazard maps. The method also has been used to develop or adjust GMPEs (e.g., for differences in generic site conditions) in many other regions of the world. A comparison of four ENA hard-rock GMPEs developed using the HEM and a fifth firm-rock GMPE developed using the closely related Referenced Empirical Approach (REA) show that they fall into three distinct groups based on differences in (1) the methods, models, and parameters used to calculate the host-to-target adjustment factors and (2) the selection of the host empirical GMPEs. A different set of groups are implied from the aleatory variability models. General guidance is provided to aid the user in the selection and weighting of these five GMPEs for application in seismic hazard analysis.